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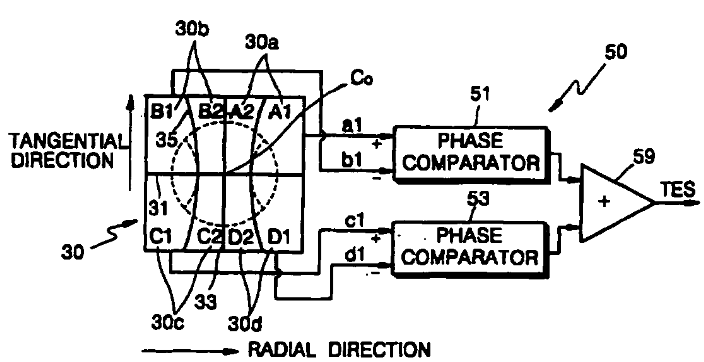
(54) Tracking error signal detecting apparatus and reproduction signal detecting apparatus

(57) There are provided a tracking error signal detecting apparatus with improvement in offset due to gain characteristics and/or a difference in the depth between pits by providing an improved sectioning structure of an 8-sectional photodetector (30) having inner and outer sectional plates (A2, B2, C2, D2; A1, B1, C1, D1), the radial widths of which vary along ± tangential directions from the center of the photodetector (30), and a reproduction signal detecting apparatus with reduced crosstalk noise. Therefore, the tracking error signal detecting apparatus can allow accurate tracking control in a high-density recording medium having relatively narrow tracks. Also, the reproduction signal detecting apparatus can correct signal distortion due to a difference between phase characteristics of detection signals of inner and outer sectional plates of a photodetector (30) even during reproduction of an information signal from a high-density recording medium having relatively narrow tracks, thereby detecting an improved reproduction signal with greatly reduced crosstalk.

FIG. 4



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Description

[0001] The present invention relates to a tracking error signal detecting apparatus and a reproduction signal detecting apparatus, and more particularly, to a tracking error signal detecting apparatus for improving the precision in detecting a tracking error signal and a reproduction signal detecting apparatus for detecting a reproduction signal with crosstalk noise greatly reduced.

[0002] Conventional methods for detecting tracking errors by receiving light radiated from a light source of an optical pickup device and reflected from a disk include a method for detecting a tracking error signal (TES) by differential phase detection (DPD).

[0003] Referring to Figure 1, light radiated onto a ROM-type disk is reflected and is diffracted into 0th-order maximum and ±1st-order maxima by recording marks such as pits (P). After traveling back through the optical pickup, the light received at a photodetector 1 substantially consists of the 0th-order maximum overlapped by ±1st-order maxima in a radial direction. Here, in the case of a high-density disk having narrow tracks, such as a next-generation digital versatile disk (DVD), which is called a HD-DVD, the 0th-order maximum and ±1st-order maxima overlap, while +1st-order maximum and -1st-order maximum do not overlap each other.

[0004] Phase signals of portions where the 0th-order maximum and the +1st-order maximum overlap and where the 0th-order maximum and the -1st-order maximum overlap have different features from a phase signal of the 0th-order maximum only. Thus, in the case of the high-density disk having narrow tracks, if a tracking error signal is detected by a general DPD method in which detection signals of diagonal sectional plates A/C and B/D are simply subtracted, great noise is caused in the tracking error signal due to crosstalk between adjacent tracks.

[0005] In order to detect a tracking error signal with reduced crosstalk noise from adjacent tracks, there has been proposed a method in which an 8-sectional photodetector 20 is employed, as shown in Figure 2.

[0006] The 8-sectional photodetector 20 is divided into 4 parts in a row direction corresponding to the radial direction of a disk and is divided into 2 parts in a column direction corresponding to the tangential direction of a disk, so that its sections are arranged in a 2 × 4 matrix. Here, the respective 2-sectional plates A1/A2, B1/B2, C1/C2 and D1/D2 correspond to the sectional plates A, B, C and D of the photodetector 20 shown in Figure 1. The sectional plates A2, B2, C2 and D2 are positioned at the inner sides of A1, B1, C1 and D1, respectively.

[0007] The tracking error signal is produced from detection signals of the 8-sectional photodetector 20 as follows.

[0008] Referring to Figure 3, a sum signal (a1+c1) of detection signals a1 and c1 of outer sectional plates A1 and C1 arranged in a diagonal direction and a signal obtained by amplifying a sum signal (a2+c2) of detection signals a2 and c2 of inner sectional plates A2 and C2 with a predetermined gain k1 are summed, and the sum signal [a1+c1+k1(a2+c2] is input to an amplifier 21 to then be amplified with a predetermined gain k2. Likewise, a sum signal (b1+d1) of detection signals b1 and d1 of outer sectional plates B1 and D1 arranged in another diagonal direction and a signal obtained by amplifying a sum signal (b2+d2) of detection signals b2 and d2 of inner sectional plates B2 and D2 with a predetermined gain k are summed. Then, the signal [k2(a1+c1+k1(a2+c2))] output from the amplifier 21 and the operation signal [b1+d1+k(b2+d2)] output from the diagonal sectional plates B1, B2, D1 and D2 are applied to a phase comparator 25 for comparison of phases, to then generate a tracking error signal TES'.

[0009] Here, if k=k1=0 and k2=1, the signals applied to the phase comparator 25 are a1+c1 and b1+d1, which corresponds to the case where a phase difference is obtained using a sum signal of detection signals of outer sectional plates arranged in a diagonal direction.

[0010] Also, if k≠0 and k1≠0, the signals applied to the phase comparator 25 are a2+c2 and b2+d2, which corresponds to the case where a phase difference is obtained using a sum signal of detection signals of inner sectional plates arranged in a diagonal direction.

[0011] According to the aforementioned tracking error signal detecting apparatus, since a phase difference is obtained by selectively amplifying detection signals of inner sectional plates A2, B2, C2 and D2 with a predetermined gain factors and then adding the amplified signals and detection signals of outer sectional plates A1, B1, C1 and D1, a tracking error signal with reduced crosstalk noise can be generated.

[0012] Although the conventional tracking error signal detecting apparatus reduces crosstalk noise to a degree, when it is employed with a high-density disk having narrow tracks, in which tangential phase characteristics are obscured, the gain of tracking error signals is very low, that is, the precision is poor.

[0013] The beams received at sectional plates positioned at different locations in a tangential direction of a track have different phase characteristics at a starting area and an ending area of a recording mark such as a pit. However, if detection signals of diagonally adjacent plates are summed like in the conventional tracking error signal detecting apparatus, tangential phase characteristics are offset, which results in tracking error signals having a low gain, that is, poor precision.

[0014] Also, in the conventional tracking error signal detecting apparatus, since sum signals of detection signals of diagonally adjacent sectional plates are used, a phase difference between the sum signals is offset due to a difference in the depth between pits. Thus, if an objective lens (not shown) is shifted, a large offset may occur to the tracking error signals.

[0015] The present invention has been made in

view of the points described above, and it is an aim of embodiments of the present invention to provide a tracking error signal detecting apparatus with improvement in gain characteristics and/or offset due to a difference in the depth between pits by providing an improved sectioning structure of an 8-sectional photodetector, and a reproduction signal detecting apparatus with reduced crosstalk noise.

[0016] According to a first aspect of the invention, there is provided a tracking error signal detecting apparatus including a photodetector for receiving light reflected/diffracted from a recording medium, and a circuit unit for performing operations on detection signals of the photodetector and producing a tracking error signal, the apparatus characterized in that the photodetector includes four light receiving regions arrayed counterclockwise, the dividing lines of which are substantially parallel to the radial and tangential directions of the recording medium, each of the four light receiving regions are further bisected to produce an inner sectional plate and an outer sectional plate, the radial widths of which vary along ± tangential directions from the center of the photodetector, so that 8 inner and outer sectional plates arrayed in a 2 × 4 matrix are formed, the directions of columns and rows of the sectional plates corresponding to the radial and tangential directions of the recording medium, and the circuit unit compares the phases of the light receiving regions positioned in the same row and then produces a tracking error signal from a phase difference signal.

[0017] Preferably, the circuit unit amplifies at least some of the detection signals of the inner and/or outer sectional plates positioned in one diagonal direction with a predetermined gain, compares phase differences between the amplified signals and at least some of the detection signals of inner and/or outer sectional plates positioned in the other diagonal direction, and detects a tracking error signal from a phase difference signal.

[0018] Preferably, the inner sectional plates are formed such that their widths are relatively narrower at the center of the photodetector and relatively wider along ± tangential directions.

[0019] For example, the lines dividing the inner light receiving regions from the outer sectional plates are preferably curved lines, and the maximum width of each of the inner sectional plates is preferably larger than the radius of received 0th-order diffracted light.

[0020] The reproduction signal detecting apparatus may include a photodetector for receiving light reflected/diffracted from a recording medium, and a circuit unit for performing operations on detection signals of the photodetector and producing a reproduction signal, the photodetector includes four light receiving regions arrayed counterclockwise, the dividing lines of which are substantially parallel to the radial and tangential directions of the recording medium, each of the four light receiving regions are further bisected to produce an inner sectional plate and an outer sectional plate, the radial widths of which vary along ± tangential directions from the center of the photodetector, so that 8 inner and outer sectional plates arrayed in a 2 × 4 matrix are formed, the directions of columns and rows of the sectional plates corresponding to the radial and tangential directions of the recording medium, and the circuit unit includes an amplifier for amplifying a sum signal of detection signals of the outer sectional plates, and an adder for adding a sum signal of detection signals of the inner sectional plates and the output signal of the amplifier.

[0021] According to another aspect of the present invention, the circuit unit may further include a time delay for time-delaying detection signals of the inner and/or outer sectional plates positioned in one row.

[0022] Preferably, the circuit unit comprises: a first phase comparator for comparing phases of detection signals of a pair of outer sectional plates positioned in one row and outputting a phase difference signal; a second phase comparator for comparing phases of detection signals of a pair of outer sectional plates positioned in the other row and outputting a phase difference signal; and an adder for adding phase difference signals output from the first and second phase comparators and outputting a tracking error signal.

[0023] The circuit unit may comprise: a first phase comparator for comparing phases of detection signals of a pair of inner sectional plates positioned in one row and outputting a phase difference signal; a second phase comparator for comparing phases of detection signals of a pair of inner sectional plates positioned in the other row and outputting a phase difference signal; and an adder for adding phase difference signals output from the first and second phase comparators and outputting the tracking error signal.

[0024] The circuit unit may comprise: first and second phase comparators for comparing phases of detection signals of a pair of outer and inner sectional plates positioned in one row, respectively, and outputting phase difference signals; third and fourth phase comparators for comparing phases of detection signals of a pair of outer and inner sectional plates positioned in the other row, respectively, and outputting phase difference signals; a first adder for adding the phase difference signals output from the first and third phase comparators to detect a first tracking error signal based on the detection signals of the outer sectional plates; a second adder for adding the phase difference signals output from the second and fourth phase comparators to detect a second tracking error signal based on the detection signals of the inner sectional plates; and an operator for summing the first and second tracking error signals detected by the first and second adders to output a tracking error signal.

[0025] Preferably, the operator amplifies at least one of the first and second tracking error signals output from the first and second adders with a predetermined gain to produce a tracking error signal.

[0026] Preferably, the circuit unit comprises: a first operator for amplifying a detection signal of one inner sectional plate positioned in one row with a predetermined gain and adding the amplified signal and a detection signal of the corresponding outer sectional plate; a second operator for amplifying a detection signal of the other inner sectional plate positioned in one row with a predetermined gain and adding the amplified signal and a detection signal of the corresponding outer sectional plate; a third operator for amplifying a detection signal of one inner sectional plate positioned in the other row with a predetermined gain and adding the amplified signal and a detection signal of the corresponding outer sectional plate; a fourth operator for amplifying a detection signal of the other inner sectional plate positioned in the other row with a predetermined gain and adding the amplified signal and a detection signal of the corresponding outer sectional plate; a first phase comparator for comparing phases of sum signals output from the first and second operatorsand outputting a phase difference signal; a second phase comparator for comparing phases of sum signals output from the third and fourth operators and outputting a phase difference signal; and an adder for adding the phase difference signals output from the first and second phase comparators to output a tracking error signal.

[0027] Preferably, the inner sectional plates are formed such that their widths are relatively narrower at the center of the photodetector and relatively wider along ± tangential directions.

[0028] Preferably, the lines dividing the inner light receiving regions from the outer sectional plates are curved lines.

[0029] Preferably, the maximum width of each of the inner sectional plates is larger than the radius of received 0th-order diffracted light.

[0030] Preferably, the width of each of the inner sectional plates linearly increases from the center of the photodetector outward in the ± tangential directions.

[0031] Preferably, each of the inner sectional plates has a shape selected from a trapezoid, a right-angle triangle and an isosceles triangle.

[0032] According to another aspect, there is provided a tracking error signal detecting apparatus having a photodetector for receiving light reflected/ diffracted from a recording medium, and a circuit unit for performing operations on detection signals of the photodetector and producing a tracking error signal, the apparatus characterized in that the photodetector includes four light receiving regions arrayed counterclockwise, the dividing lines of which are substantially parallel to the radial and tangential directions of the recording medium, each of the four light receiving regions are further bisected to produce an inner sectional plate and an outer sectional plate, the radial widths of which vary along ± tangential directions from the center of the photodetector, so that 8 inner and outer sectional plates arrayed in a 2 × 4 matrix are formed, the directions of columns and rows of the sectional plates corresponding to the radial and tangential directions of the recording medium, and that the circuit unit amplifies at least some of the detection signals of the inner and/or outer sectional plates positioned in one diagonal direction with a predetermined gain, compares phase differences between the amplified signals and at least some of the detection signals of inner and/or outer sectional plates positioned in the other diagonal direction, and detects a tracking error signal from a phase difference signal.

[0033] The circuit unit may comprise: an amplifier for amplifying a sum signal of detection signals of outer or inner sectional plates positioned in one diagonal direction with a predetermined gain; and a phase comparator for comparing phases of a sum signal of detection signals of outer or inner sectional plates positioned in the other diagonal direction to detect a tracking error signal.

[0034] The circuit unit may comprise: a first operator for receiving detection signals of inner and outer sectional plates positioned in one diagonal direction, amplifying a sum signal of detection signals of the inner sectional plates with a first predetermined gain and adding the amplified signal and a sum signal of detection signals of the outer sectional plates; a second operator for receiving detection signals of inner and outer sectional plates positioned in the other diagonal direction, amplifying a sum signal of detection signals of the inner sectional plates with a second predetermined gain and adding the amplified signal and a sum signal of detection signals of the outer sectional plates; an amplifier for amplifying a signal output from one of the first and second operators with a third predetermined gain; and a phase comparator for comparing phases of a signal output from the other of the first and second operators and a signal output from the amplifier to produce a tracking error signal.

[0035] The sum of the first and second predetermined gains is preferably a constant value.

[0036] The circuit unit may further comprise a time delay for time-delaying detection signals of the inner and/or outer sectional plates positioned in one row.

[0037] The inner sectional plates may be formed such that their widths are relatively narrower at the center of the photodetector and relatively wider along ± tangential directions.

[0038] Preferably, the lines dividing the inner light receiving regions from the outer sectional plates are curved lines.

[0039] Preferably, the maximum width of each of the inner sectional plates is larger than the radius of received 0th-order diffracted light.

[0040] Preferably, the width of each of the inner sectional plates linearly increases from the center of the photodetector outward in the ± tangential directions.

[0041] Preferably, each of the inner sectional has a shape selected from a trapezoid, a right-angle triangle and an isosceles triangle.

[0042] In another aspect, there is provided a reproduction signal detecting apparatus having a photodetector for receiving light reflected/ diffracted from a recording medium, and a circuit unit for performing operations on detection signals of the photodetector and producing a reproduction signal, the apparatus characterized in that the photodetector includes four light receiving regions arrayed counterclockwise, the dividing lines of which are substantially parallel to the radial and tangential directions of the recording medium, each of the four light receiving regions are further bisected to produce an inner sectional plate and an outer sectional plate, the radial widths of which vary along ± tangential directions from the center of the photodetector, so that 8 inner and outer sectional plates arrayed in a 2×4 matrix are formed, the directions of columns and rows of the sectional plates corresponding to the radial and tangential directions of the recording medium, and that the circuit unit comprises: an amplifier for amplifying a sum signal of detection signals of the outer sectional plates; and an adder for adding a sum signal of detection signals of the inner sectional plates and the output signal of the amplifier.

[0043] The circuit unit may further comprise a time delay for time-delaying detection signals of the inner and/or outer sectional plates positioned in one row.

[0044] The respective light receiving regions may be bisected such that the width of each of the inner sectional plates linearly increases from the center of the photodetector outward in the ± tangential directions.

[0045] For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which:

Figure 1 is a perspective view illustrating light reflected/diffracted from a general recording medium;

Figures 2 and 3 illustrate a tracking error signal detecting apparatus employing a conventional 8-sectional photodetector;

Figure 4 is a diagram schematically illustrating a tracking error signal detecting apparatus according to an embodiment of the present invention;

Figure 5 through 8 are plan views schematically illustrating another example of a photodetector shown in Figure 4;

Figure 9 is a graph showing tracking error signals output from the tracking error signal detecting apparatus shown in Figure 4;

Figure 10 is a graph showing tracking error signals output from the conventional tracking error signal detecting apparatus;

Figures 11 through 13 are block diagrams illustrating another example of a circuit unit shown in Figure 4;

Figure 14 is a diagram schematically illustrating a tracking error signal detecting apparatus according to another embodiment of the present invention;

Figures 15 through 17 are block diagrams illustrating another example of a circuit unit shown in Figure 14;

Figure 18 is a diagram schematically illustrating a reproduction signal detecting apparatus according to an embodiment of the present invention; and

Figure 19 is a diagram schematically illustrating a reproduction signal detecting apparatus according to another embodiment of the present invention.

[0046] Referring to Figure 4, a tracking error signal detecting apparatus according to an embodiment of the present invention includes a photodetector 30 for receiving the light reflected/diffracted from a recording medium such as a disk (10 of Figure 1), and a circuit unit 50 for performing operations with respect to detection signals of the photodetector 30 to produce a tracking error signal TES. Here, the photodetector 30 receives incident light which is reflected from the recording medium, and the detection signals thereof are used in detecting the tracking error signal TES and detecting a reproduction signal of the recording medium to be described later.

[0047] The photodetector 30 includes four light receiving regions 30a (A1/A2), 30b (B1/B2), 30c (C1/C2) and 30d (D1/D2) arrayed counterclockwise in a 2×2 matrix, the light receiving regions being produced such that the photodetector 30 is bisected in a direction corresponding to the tangential direction of the recording medium and further bisected in a direction corresponding to the radial direction of the recording medium, where the tangential direction refers to a direction of information sequences recorded on the recording medium and the radial direction refers to a direction perpendicular to the information sequences. The respective light receiving regions 30a, 30b, 30c and 30d are bisected to have inner sectional plates A2, B2, C2 and D2, the radial widths of which vary along the ± tangential directions from the center C_0 of the photodetector 30.

[0048] Thus, the photodetector 30 is arrayed in 2×4 matrix and consists of 8 sectional plates A1, A2, B1, B2, C1, C2, D1 and D2 for independently performing photoelectric conversion. The outer sectional plates A1, B1, C1 and D1 and the inner sectional plates A2, B2, C2 and D2 are arranged counterclockwise.

[0049] As shown in Figure 2, the light reflected/diffracted from a ROM-type high-density recording medium having relatively narrow tracks is diffracted into 0th-order diffracted light and ±1st-order diffracted light along the radial direction. When the 0th-order diffracted light and the ±1st-order diffracted light overlap and +1st-order diffracted light and -1st-order diffracted light do not overlap, the outer sectional plates A1, B1, C1 and D1 receive light mainly from the overlapping area of the 0th-order diffracted light and the +1st-order diffracted light and from the overlapping area of the 0th-order diffracted light and the -1st-order diffracted light, and the inner sectional plates A2, B2, C2 and D2 receive light only from the area of the 0th-order diffracted light.

[0050] In other words, the inner sectional plates A2, B2, C2 and D2 are preferably formed such that the widths thereof are relatively narrow at the center C_0 of the photodetector 30 and become wider along the ± tangential directions.

[0051] However, in the case of employing a low-density recording medium having a relatively large track pitch or RAM-type high-density recording medium having a land/groove configuration, in which some of ±1st-order diffracted light reflected/diffracted from the recording medium simultaneously overlap with 0th-order diffracted light, the respective light receiving regions 30a, 30b, 30c and 30d are preferably bisected to have inner sectional plates A2, B2, C2 and D2, the widths of which are relatively wide at the center C_0 of the photodetector 30 and become narrower along the ± tangential directions. Here, the inner sectional plates A2, B2, C2 and D2 receive the light from an area where the 0th-order diffracted light and the ±1st-order diffracted light overlap simultaneously.

[0052] The sectioning structure of the 8-sectional photodetector 30 according to the present invention will now be described through detailed embodiments. As shown in Figures 4 and 5, a dividing line 35 of each of the respective light receiving regions 30a, 30b, 30c and 30d is preferably a curved line having a predetermined curvature so as to separately receive light from an area of the 0th-order diffracted light and an overlapping area of the 0th-order diffracted light and the ±1st-order diffracted light.

[0053] Here, the dividing line 35 is tangent to the overlapping area of the 0th-order diffracted light and the ±1st-order diffracted light at the intersection with a row-directional dividing line 31.

[0054] Figure 4 illustrates that the dividing line 35 is substantially a part of an ellipse, and Figure 5 illustrates that the dividing line 35 is a part of a parabola formed such that the maximum width of each of the inner sectional plates A2, B2, C2 and D2 is greater than the radius of the 0th-order diffracted light received thereat. The dividing line 35 shown in Figure 5 more closely fits the boundary of the overlapping area of the 0th-order diffracted light and the ±1st-order diffracted light and thus has an advantage in that it can minimize the amount of 0th-order diffracted light received at the outer sectional plates A1, B1, C1 and D1.

[0055] Alternatively, the respective light receiving regions 30a, 30b, 30c and 30d may be bisected such that the width of each of the inner sectional plates A2, B2, C2 and D2 linearly increases from the center C_0 of the photodetector 30 outward in the ± tangential directions.

[0056] For example, the respective light receiving regions 30a, 30b, 30c and 30d may be bisected such that each of the inner sectional plates A2, B2, C2 and D2 has the shape of a trapezoid, a right triangle or an isosceles triangle, as viewed at positions spaced a predetermined distance apart from the center C_0 of the photodetector 30 outward in the ± tangential directions, as shown in Figures 6 through 8.

[0057] The tracking error signal detecting apparatus according to an embodiment of the present invention employs the 8-sectional photodetector 30 having various sectioning configurations as described above, and the photodetector 30 having the sectioning configuration shown in Figure 4 will be described below by way of example.

[0058] Referring back to Figure 4, the circuit unit 50 compares the phases of detection signals of inner and/or outer sectional plates positioned in the same row with each other and detects a tracking error signal from phase difference signals.

[0059] For example, as shown in Figure 4, the circuit unit 50 includes a pair of phase comparators 51 and 53 for comparing phases of input signals, and an adder 59 for adding phase difference signals output from the phase comparators 51 and 53.

[0060] Detection signals a1 and b1 of the outer sectional plates A1 and B1 positioned in the first row are input to the phase comparator 51 for phase comparison. Detection signals c1 and d1 of the outer sectional plates C1 and D1 positioned in the second row are input to the phase comparator 53 for phase comparison.

[0061] Thus, a tracking error signal TES output from the adder 59 is obtained by adding a phase difference signal between the detection signals a1 and b1 of the outer sectional plates A1 and B1 and a phase difference signal between the detection signals c1 and d1 of the outer sectional plates C1 and D1 positioned in the same row, that is, in the same row in the tangential direction, the phase difference signals being applied from the phase comaprators 51 and 53, respectively.

[0062] Figure 9 is a graph showing a tracking error signal TES detected from the circuit unit 50 of the tracking error signal detecting apparatus according to an embodiment of the present invention, shown in Figure 4, and Figure 10 is a graph showing a tracking error signal TES' generated by the conventional tracking error signal detecting apparatus shown in Figures 2 and 3. Here, the abscissa indicates a light spot moving across tracks of a recording medium in a radial direction, and the ordinate indicates a change in the tracking error signal depend-

ing on the movement of a light spot.

[0063] Comparing Figures 9 and 10, the tracking error signal TES detected by the tracking error signal detecting apparatus according to the present invention has a large gain and noticeably improved noise characteristics, compared to the tracking error signal TES' generated by obtaining the diagonal sum signals a1+c1 and b1+d1 of the detection signals a1, b1, c1 and d1 of the outer sectional plates A1, B1, C1 and D1 of the conventional photodetector (20 of Figure 2) and then comparing the phases thereof.

[0064] In another embodiment of the circuit unit 50, as shown in Figure 11, the tracking error signal may be generated using the detection signals a2, b2, c2 and d2 of the inner sectional plates A2, B2, C2 and D2, instead of the detection signals a1, b1, c1 and d1 of the outer sectional plates A1, B1, C1 and D1.

[0065] In other words, detection signals a2 and b2 of the inner sectional plates A2 and B2 positioned in the first row are applied to a phase comparator 151 and a phase difference signal is output therefrom. Also, detection signals c2 and d2 of the inner sectional plates C2 and D2 positioned in the second row are applied to another phase comparator 153 and a phase difference signal is output therefrom. An adder 159 adds the phase difference signals and outputs a tracking error signal.

[0066] In a still another embodiment, the circuit unit 50, as shown in Figure 12, has a combined structure of the configurations shown in Figures 4 and 11, to detect a tracking error signal using detection signals a1, a2, b1, b2, c1, c2, d1 and d2 of all inner and outer sectional plates A1, A2, B1, B2, C1, C2, D1 and D2.

[0067] In other words, a tracking error signal TES1 (see Figure 9) obtained by an operation of the detection signals a1, b1, c1 and d1 of the outer sectional plates A1, B1, C1 and D1, and a tracking error signal TES2 obtained by an operation of the detection signals a2, b2, c2 and d2 of the inner sectional plates A2, B2, C2 and D2, are summed by an operator 60 to produce a tracking error signal TES. Here, the TES2 is a tracking error signal obtained by operation of the detection signals a2, b2, c2 and d2 of the inner sectional plates A2, B2, C2 and D2, and corresponds to a tracking error signal output from the adder 159 shown in Figure 11.

[0068] The operator 60 amplifies one tracking error signal TES2 of the tracking error signals TES1 and TES2 output from the adder 59 and 159 with a predetermined gain k and then sums the other tracking error signal TES1 and the amplified signal k*TES2 to produce a tracking error signal TES [=TES1+(k*TES2)].

[0069] Here, the operator 60 may amplify the tracking error signal TES1 with a predetermined gain. Otherwise, the operator 60 amplifies both the tracking error signal TES1 and TES2 with appropriate gains and then sums the amplified signals and produces the tracking error signal TES.

[0070] Alternatively, the circuit unit 50, as shown in Figure 13, may include first through fourth operators 161, 162, 163 and 164, first and second phase comparators 165 and 167 and an adder 169, and may produce a tracking error signal by phase-comparing sum signals a1+ka2, b1+kb2, c1+kc2 and d1+kd2 of signals ka2, kb2, kc2 and kd2 obtained by amplifying detection signals a2, b2, c2 and d2 of the inner sectional plates A2, B2, C2 and D2 with a predetermined gain k, and detection signals a1, b1, c1 and d1 of the corresponding outer sectional plates A1, B1, C1 and D1, and adding phase difference signals.

[0071] The detection signals a1 and a2 of the outer and inner sectional plates A1 and A2 forming the light receiving regions A1 and A2 positioned in the first row, are applied to the first operator 161. The first operator 161 amplifies the detection signal a2 of the inner sectional plate A2 with a predetermined gain k and then sums the same with the detection signal a1 of the outer sectional plate A1. Thus, output signal of the first operator 161 becomes a1+ka2.

[0072] Likewise, the detection signals b1 and b2, c1 and c2, and d1 and d2 of the other light receiving regions B1 and B2, C1 and C2, and D1 and D2 are applied to the second through fourth operators 162, 163 and 164 to then be operated. The second through fourth operators 162, 163 and 164 output operation signals b1+kb2, c1+kc2 and d1+kd2.

[0073] Signals detected from the light receiving regions A1 and A2, and B1 and B2 positioned in the first row and having passed through the first and second operators 161 and 162 are phase-compared by the first phase comparator 165. Likewise, signals detected from the light receiving regions C1 and C2, and D1 and D2 positioned in the second row and having passed through the third and fourth operators 163 and 164 are phase-compared by the second phase comparator 167.

[0074] The phase difference signals output from the first and second phase comparators 165 and 167 are summed by the adder 169. Then, the adder 169 outputs the tracking error signal TES.

[0075] The circuit unit 50 having the aforementioned configuration sums detections signals of outer and inner sectional plates forming the respective light receiving regions 30a, 30b, 30c and 30d with signals obtained by amplifying the detection signals of the inner sectional plates with a predetermined gain, and phase differences of signals from the sectional plates positioned in the same row are compared. Thus, a difference in the signal characteristic between detection signals of the outer and inner sectional plates can be compensated for, thereby detecting a tracking error signal with a large gain and reduced crosstalk noise.

[0076] Figure 14 illustrates a tracking error signal detecting apparatus according to another embodiment of the present invention, in which a circuit unit 250 detects a tracking error signal from phase difference signals by amplifying at least some of the detection signals of inner and/or outer sectional plates positioned in one diagonal direction with a predetermined gain and

phase-comparing the amplified signals with at least some of the detection signals of inner and/or outer sectional plates positioned in the other diagonal direction.

[0077] For example, as shown in Figure 14, the circuit unit 250 includes an amplifier 260 for amplifying a sum signal of the detection signals a1 and c1 of the outer sectional plates A1 and C1 positioned in one diagonal direction, and a phase comparator 251 for comparing phases of a sum signal b1+d1 of the detection signals b1 and d1 of the outer sectional plates B1 and D1 positioned in the other diagonal direction and an output signal k2(a1+c1) of the amplifier 260 to detect a tracking error signal TES. Here, the gain k2 is a constant other than zero.

[0078] The aforementioned tracking error signal detecting apparatus sums detection signals of outer sectional plates positioned in a diagonal direction like in the general DPD method. However, the apparatus receives only the light of overlapping areas of the 0th-order maximum and +1st-order maximum and the 0th-order maximum and -1st-order maximum from outer sectional plates, amplifies the sum signal of one diagonal direction with a predetermined gain and then compares the phase of the amplified signal with that of the sum signal of the other diagonal direction. Thus, the tracking error signal TES has a larger gain and less noise than the conventional tracking error signal TES'.

[0079] Here, the circuit unit 250 of Figure 14 may be connected to detect a tracking error signal from detection signals of the inner sectional plates A2, B2, C2 and D2.

[0080] The circuit unit 250 of Figure 14 may further include a time delay 240 at output ends of the outer sectional plates A1 and B1, as shown in Figure 15.

[0081] In this case, the detection signals a1 and b1 of the outer sectional plates A1 and B1 pass through the time delay 240 to then be converted into time-delayed signals a11 and b11, which are summed with the detection signals c1 and d1 of the outer sectional plates C1 and D1 positioned in another row to then be applied to the amplifier 260 and the phase comparator 251, like in Figure 14.

[0082] If the detection signals a1 and b1 of the outer sectional plates A1 and B1 positioned in one row are time-delayed to detect a track error signal TES, as shown in Figure 15, it is possible to compensate for a tracking error signal offset generated when an objective lens (not shown) is shifted due to a phase difference offset of diagonal sum signals, caused by a change in the pit depth, occurring to practical recording media, thereby detecting a more accurate tracking error signal.

[0083] In other words, if a difference in the pit depth of a recording medium is generated, the conventional tracking error signal detecting apparatus detects a tracking error signal by summing detection signals of two diagonal directions and then subtracting the diagonal sum signals. Thus, signal deterioration is severe. On the other hand, the circuit unit 250 of Figure 15 according to the present invention first performs an operation of detection signals of sectional plates positioned in the same diagonal line, and time-delay and amplification are then performed to produce a tracking error signal. Thus, since phase deterioration due to signal distortion caused by a change in the pit depth is greatly improved, a tracking error signal with greatly reduced offset can be generated.

[0084] Alternatively, unlike the circuit unit 250 according to another embodiment of the present invention, as shown in Figure 14, in which a tracking error signal is generated using only the detection signals of the inner or outer sectional plates, detection signals of both the inner and outer sectional plates A2, B2, C2 and D2 and A1, B1, C1 and D1 can be used in detecting a tracking error signal, as shown in Figure 16.

[0085] In other words, the circuit unit 250 may detect a tracking error signal by appropriately operating detection signals of sectional plates positioned in the respective diagonal directions, and phase-comparing the operation signals. The circuit unit 250 has the following configuration.

[0086] Detection signals a1, c1, a2 and c2 of the outer and inner sectional plates A1, C1, A2, C2 positioned in one diagonal direction are applied to a first operator 280. The first operator 280 amplifies a sum signal a2+c2 of detection signals a2 and c2 of the inner sectional plates A2 and C2 with a predetermined gain k1 and adds a sum signal a1+c1 of detection signals a1 and c1 of the outer sectional plates A1 and C1 with the amplified signal k1(a2+c2).

[0087] The output signal a1+c1+k1(a2+c2) of the first operator 280 is again amplified by an amplifier 289 with a predetermined gain k2.

[0088] Detection signals b1, d1, b2 and d2 of the outer and inner sectional plates B1, D1, B2, D2 positioned in the other diagonal direction are applied to a second operator 285. The second operator 285 amplifies a sum signal b2+d2 of detection signals b2 and d2 of the inner sectional plates B2 and D2 with a predetermined gain k1 and adds a sum signal b1+d1 of detection signals b1 and d1 of the outer sectional plates B1 and D1 with the amplified signal k(b2+d2).

[0089] The output signal of the amplifier 289 and the output signal b1+d1+k(b2+d2) are applied to a phase comparator 251 to then be phase-compared. The phase comparator 251 outputs a tracking error signal TES.

[0090] Here, the gains k and k1 are constants, and the gain k2 is preferably a constant other than zero. Also, the sum k+k1 of the gains k and k1 is preferably a constant. If the gains k and k1 are both zero, the same result as shown in Figure 14 is caused.

[0091] The circuit unit 250 shown in Figure 16 may further include a time delay 240 at the output ends of the sectional plates A1, A2, B1 and B2 positioned in one row, as shown in Figure 17.

[0092] In this case, the detection signals a1, a2, b1

and b2 of the sectional plates A1, A2, B1 and B2 pass through the time delay 240 to then be converted into time-delayed signals a11, a22, b11 and b22, respectively. The time-delayed signals a11 and a22 and the detection signals c1 and c2 of the sectional plates C1 and C2 positioned in the diagonal direction thereof, and the time-delayed signals b11 and b22 and the detection signals d1 and d2 of the sectional plates D1 and D2 positioned in the diagonal direction thereof, are applied to the first and second operators 280 and 285, respectively, like in Figure 16.

[0093] The output signal $a11+c1+k1\times(a22+c2)$ of the first operator 280 is amplified by the amplifier 289 with a predetermined gain k2.

[0094] The output signal $b11+d1+k1\times(b22+d2)$ of the second operator 285 and the output signal $k2\times[a11+c1+k1\times(a22+c2)]$ of the amplifier 289 are applied to the phase comparator 251 to then be phase-compared. The phase comparator 251 outputs a tracking error signal TES.

[0095] In the circuit unit 250 having the aforementioned configuration, like in Figure 15, signal distortion can be obscured by time delay and amplification even when there is a difference between pit depths of a recording medium. Thus, even in the case of a lens shift, a tracking error signal with greatly reduced offset can be generated.

[0096] In the case where the light spot deviates 0.1 μm from the center of the pit or mark sequence recorded on the recording medium, the tracking error signals detected by the embodiments of the above-described tracking error signal detecting apparatus preferably have approximately 0.5 in the minimum value of $\Delta t/Tw$, where Tw represents a period of a channel clock of the recording/reproducing apparatus and Δt represents the detected average phase difference time, and preferably have approximately 0.2 in the maximum value of $|(T1-T2)/(T1+T2)|$, where T1 represents the maximum value of the tracking error signal, which is a positive value, and T2 represent the minimum value of the tracking error signal, which is a negative value.

[0097] Also, in the embodiments of the above-described tracking error signal detecting apparatus, phase comparators are provided for phase-comparing input signals through selectively blocking or amplifying the input signals according to the frequency band, digitization, phase-comparison of digitized signals and integration of the phase-compared signals, and outputting tracking error signals

[0098] Figure 18 is a diagram schematically illustrating a reproduction signal detecting apparatus according to an embodiment of the present invention. The reproduction signal detecting apparatus includes an 8-sectional photodetector 30 and a circuit unit 300 for reproducing information of a recording medium from detection signals of the photodetector 30. Here, the photodetector 30 may be one of the 8-sectional photodetectors shown in Figures 4 through 8.

[0099] The circuit unit 300 for detecting a reproduction signal includes an amplifier 310 for amplifying a sum signal $a1+b1+c1+d1$ of detection signals a1, b1, c1 and d1 of outer sectional plates A1, B1, C1 and D1 of the photodetector 30 with a predetermined gain k, and an adder 350 for adding a sum signal $a2+b2+c2+d2$ of detection signals a2, b2, c2 and d2 of inner sectional plates A2, B2, C2 and D2 of the photodetector 30 and an output signal of the amplifier 310, to then output a reproduction signal.

[0100] Here, the gain k is a value which is determined for maximizing the magnitude of the reproduction signal and minimizing the jitter and error ratio of the reproduction signal.

[0101] The circuit unit 300 may further include amplifiers AMP's for uniformly amplifying signals, between the amplifier 310 and the adder 350, and along the transmission path of the sum signal $a2+b2+c2+d2$ of detection signals a2, b2, c2 and d2 of inner sectional plates A2, B2, C2 and D2, and pre-equalizers for correcting phase distortion of signals. Otherwise, the circuit unit 300 may further an equalizer at the output end of the adder 350.

[0102] As described above, the reproduction signal detecting apparatus according to an embodiment of the present invention amplifies the sum signal $a1+b1+c1+d1$ of detection signals a1, b1, c1 and d1 of outer sectional plates A1, B1, C1 and D1 with a predetermined gain k and sums the amplified signal with the sum signal $a2+b2+c2+d2$ of detection signals a2, b2, c2 and d2 of inner sectional plates A2, B2, C2 and D2, to thus detect a reproduction signal.

[0103] Figure 19 is a diagram schematically illustrating a reproduction signal detecting apparatus according to another embodiment of the present invention. A circuit unit 300 according to this embodiment is featured by further including a time delay 340 for time-delaying detection signals a1, a2, b1 and b2 of sectional plates A1, A2, B1 and B2 positioned in one row of the photodetector 30.

[0104] The reproduction signal detecting apparatus according to another embodiment of the present invention amplifies a sum signal $a11+b11+c1+d1$ of time-delayed signals a11 and b11 of detection signals a1 and b1of outer sectional plates A1 and B1 and detection signals c1 and d1 of outer sectional plates C1 and D1 with a predetermined gain k, and sums the amplified signal with a sum signal $a22+b22+c2+d2$ of time-delayed signals a22 and b22 of detection signals a2 and b2 of inner sectional plates A2 and B2 and detection signals c2 and d2 of inner sectional plates C2 and D2, to thus detect a reproduction signal.

[0105] According to the reproduction signal detecting apparatus of the present invention described in Figures 18 and 19, during reproduction of a high-density recording medium having narrow tracks, it is possible to compensate for a phase difference due to a crosstalk between adjacent tracks of detection signals of inner

sectional plates and detection signals of outer sectional plates, thereby detecting a reproduction signal with much less crosstalk than in the conventional reproduction signal detecting apparatus. In particular, during reproduction of a recording medium having a large difference in the pit depths, a crosstalk reducing effect can be enhanced by employing the reproduction signal detecting apparatus shown in Figure 19 configured to phase-delay detection signals of some sectional plates.

[0106] As described above, the tracking error signal detecting apparatus according to the present invention includes an 8-sectional photodetector the widths of which vary in a radial direction of the respective sectional plates so as to make full use of phase characteristics depending on light receiving regions, so that the detections signals of inner and outer sectional plates are operated in consideration of a difference in the phase characteristics. Therefore, a tracking error signal with a large gain and greatly reduced crosstalk between adjacent tracks can be detect. Also, phase deterioration due to signal distortion caused by a difference in pit depths can be greatly reduced by using time-delayed signals of the detection signals of some sectional plates. Thus, even when a lens shift occurs, a tracking error signal having little offset can be generated.

[0107] Therefore, the tracking error signal detecting apparatus according to the present invention can allow accurate tracking control in a high-density recording medium having relatively narrow tracks.

[0108] Also, the reproduction signal detecting apparatus according to the present invention can correct signal distortion due to a difference between phase characteristics of detection signals of inner and outer sectional plates of a photodetector even during reproduction of an information signal from a high-density recording medium having relatively narrow tracks, thereby detecting an improved reproduction signal with greatly reduced crosstalk.

[0109] Although the present invention has been described and illustrated in detail through specific embodiments, it is clearly understood that various modifications and changes may be effected within the scope of the invention.

[0110] The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0111] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0112] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0113] The invention is not restricted to the details of the foregoing embodiment(s). The invention extend to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A tracking error signal detecting apparatus having a photodetector (30) for receiving light reflected/diffracted from a recording medium, and a circuit unit (50) for performing operations on detection signals of the photodetector and producing a tracking error signal, the apparatus characterized in that the photodetector includes four light receiving regions (30a-30d) arrayed counterclockwise, the dividing lines of which are substantially parallel to the radial and tangential directions of the recording medium, each of the four light receiving regions (30a-d) are further bisected to produce an inner sectional plate and an outer sectional plate, the radial widths of which vary along ± tangential directions from the center of the photodetector (30), so that 8 inner and outer sectional plates arrayed in a 2 × 4 matrix are formed, the directions of columns and rows of the sectional plates corresponding to the radial and tangential directions of the recording medium, and that the circuit unit (50) compares the phases of the light receiving regions positioned in the same row and then produces a tracking error signal from a phase difference signal.

2. The tracking error detecting apparatus according to claim 1, wherein the circuit unit comprises:

   a first phase comparator (51) for comparing phases of detection signals of a pair of outer sectional plates (A1, B1) positioned in one row and outputting a phase difference signal;

   a second phase comparator (53) for comparing phases of detection signals of a pair of outer sectional plates (C1, D1) positioned in the other row and outputting a phase difference signal; and

   an adder (59) for adding phase difference signals output from the first and second phase comparators (51, 53) and outputting a tracking error signal.

3. The tracking error detecting apparatus according to

claim 1, wherein the circuit unit comprises:

a first phase comparator (151) for comparing phases of detection signals of a pair of inner sectional plates (A2, B2) positioned in one row and outputting a phase difference signal;

a second phase comparator (153) for comparing phases of detection signals of a pair of inner sectional plates (C2, D2) positioned in the other row and outputting a phase difference signal; and

an adder (159) for adding phase difference signals output from the first and second phase comparators and outputting the tracking error signal.

4. The tracking error detecting apparatus according to claim 1, wherein the circuit unit comprises:

first and second phase comparators (51, 151) for comparing phases of detection signals of a pair of outer (A1, B1) and inner (A2, B2)) sectional plates positioned in one row, respectively, and outputting phase difference signals;

third and fourth phase comparators (53, 153) for comparing phases of detection signals of a pair of outer (C1, D1) and inner (C2, D2) sectional plates positioned in the other row, respectively, and outputting phase difference signals;

a first adder (59) for adding the phase difference signals output from the first and third phase comparators (51, 53) to detect a first tracking error signal based on the detection signals of the outer sectional plates (A1, B1, C1, D1);

a second adder (159) for adding the phase difference signals output from the second and fourth phase comparators (151, 153) to detect a second tracking error signal based on the detection signals of the inner sectional plates (A2, B2, C2, D2); and

an operator (60) for summing the first and second tracking error signals detected by the first and second adders (59, 159) to output a tracking error signal.

5. The tracking error signal detecting apparatus according to claim 4, wherein the operator (60) amplifies at least one of the first and second tracking error signals output from the first and second adders (59, 159) with a predetermined gain to produce a tracking error signal.

6. The tracking error detecting apparatus according to claim 1, wherein the circuit unit (50) comprises:

a first operator (161) for amplifying a detection signal of one inner sectional plate (A2) positioned in one row with a predetermined gain and adding the amplified signal and a detection signal of the corresponding outer sectional plate (A1);

a second operator (162) for amplifying a detection signal of the other inner sectional plate (B2) positioned in one row with a predetermined gain and adding the amplified signal and a detection signal of the corresponding outer sectional plate (B1);

a third operator (163) for amplifying a detection signal of one inner sectional plate (C2) positioned in the other row with a predetermined gain and adding the amplified signal and a detection signal of the corresponding outer sectional plate (C1);

a fourth operator (164) for amplifying a detection signal of the other inner sectional plate (D2) positioned in the other row with a predetermined gain and adding the amplified signal and a detection signal of the corresponding outer sectional plate (D1);

a first phase comparator (165) for comparing phases of sum signals output from the first and second operators (161, 163) and outputting a phase difference signal;

a second phase comparator (167) for comparing phases of sum signals output from the third and fourth operators (163, 164) and outputting a phase difference signal; and

an adder (169) for adding the phase difference signals output from the first and second phase comparators (165, 167) to output a tracking error signal.

7. The tracking error detecting apparatus according to any one of claims 1 through 6, wherein the inner sectional plates (A2, B2, C2, D2) are formed such that their widths are relatively narrower at the center of the photodetector (30) and relatively wider along ± tangential directions.

8. The tracking error detecting apparatus according to claim 7, wherein the lines dividing the inner light receiving regions from the outer sectional plates

(A1, B1, C1, D1) are curved lines.

9. The tracking error detecting apparatus according to claim 8, wherein the maximum width of each of the inner sectional plates (A2, B2, C2, D2) is larger than the radius of received 0th-order diffracted light.

10. The tracking error detecting apparatus according to claim 7, wherein the width of each of the inner sectional plates (A2, B2, C2, D2) linearly increases from the center of the photodetector (30) outward in the ± tangential directions.

11. The tracking error detecting apparatus according to claim 10, wherein each of the inner sectional plates (A2, B2, C2, D2) has a shape selected from a trapezoid, a right-angle triangle and an isosceles triangle.

12. A tracking error signal detecting apparatus having a photodetector (30) for receiving light reflected/diffracted from a recording medium, and a circuit unit (250) for performing operations on detection signals of the photodetector (30) and producing a tracking error signal, the apparatus characterized in that the photodetector (30) includes four light receiving regions (30a-30d) arrayed counterclockwise, the dividing lines of which are substantially parallel to the radial and tangential directions of the recording medium, each of the four light receiving regions are further bisected to produce an inner sectional plate and an outer sectional plate, the radial widths of which vary along ± tangential directions from the center of the photodetector (30), so that 8 inner and outer sectional plates arrayed in a 2×4 matrix are formed, the directions of columns and rows of the sectional plates corresponding to the radial and tangential directions of the recording medium, and that the circuit unit (250) amplifies at least some of the detection signals of the inner and/or outer sectional plates positioned in one diagonal direction with a predetermined gain, compares phase differences between the amplified signals and at least some of the detection signals of inner and/or outer sectional plates positioned in the other diagonal direction, and detects a tracking error signal from a phase difference signal.

13. The tracking error detecting apparatus according to claim 12, wherein the circuit unit comprises:

an amplifier (260) for amplifying a sum signal of detection signals of outer (A1, C1) or inner (A2, C2) sectional plates positioned in one diagonal direction with a predetermined gain; and

a phase comparator (251) for comparing phases of a sum signal of detection signals of outer (B1, D1) or inner (B2, D2) sectional plates positioned in the other diagonal direction to detect a tracking error signal.

14. The tracking error detecting apparatus according to claim 12, wherein the circuit unit (250) comprises:

a first operator (280) for receiving detection signals of inner and outer sectional plates (A1, A2, C1, C2) positioned in one diagonal direction, amplifying a sum signal of detection signals of the inner sectional plates (A2, C2) with a first predetermined gain and adding the amplified signal and a sum signal of detection signals of the outer sectional plates (A1, C1);

a second operator (285) for receiving detection signals of inner and outer sectional plates (B1, B2, D1, D2) positioned in the other diagonal direction, amplifying a sum signal of detection signals of the inner sectional plates (B2, D2) with a second predetermined gain and adding the amplified signal and a sum signal of detection signals of the outer sectional plates (B1, D1);

an amplifier (289) for amplifying a signal output from one of the first and second operators (280, 285) with a third predetermined gain; and

a phase comparator (251) for comparing phases of a signal output from the other of the first and second operators (280, 285) and a signal output from the amplifier (289) to produce a tracking error signal.

15. The tracking error detecting apparatus according to claim 14, wherein the sum of the first and second predetermined gains is a constant value.

16. The tracking error detecting apparatus according to any one of claims 13 through 15, wherein the circuit unit further comprises a time delay (240) for time-delaying detection signals of the inner and/or outer sectional plates positioned in one row.

17. The tracking error detecting apparatus according to any one of claims 12 through 15, wherein the inner sectional plates (A2, B2, C2, D2) are formed such that their widths are relatively narrower at the center of the photodetector and relatively wider along ± tangential directions.

18. The tracking error detecting apparatus according to claim 17, wherein the lines dividing the inner light receiving regions from the outer sectional plates are curved lines.

19. The tracking error detecting apparatus according to claim 18, wherein the maximum width of each of the inner sectional plates is larger than the radius of received 0th-order diffracted light.

20. The tracking error detecting apparatus according to claim 17, wherein the width of each of the inner sectional plates (A2, B2, C2, D2) linearly increases from the center of the photodetector (30) outward in the ± tangential directions.

21. The tracking error detecting apparatus according to claim 20, wherein each of the inner sectional plates (A2, B2, C2, D2) has a shape selected from a trapezoid, a right-angle triangle and an isosceles triangle.

22. A reproduction signal detecting apparatus having a photodetector (30) for receiving light reflected/diffracted from a recording medium, and a circuit unit (300) for performing operations on detection signals of the photodetector (30) and producing a reproduction signal, the apparatus characterized in that the photodetector (30) includes four light receiving regions (30a-30d) arrayed counterclockwise, the dividing lines of which are substantially parallel to the radial and tangential directions of the recording medium, each of the four light receiving regions (30a-30d) are further bisected to produce an inner sectional plate and an outer sectional plate, the radial widths of which vary along ± tangential directions from the center of the photodetector (30), so that 8 inner and outer sectional plates arrayed in a 2 × 4 matrix are formed, the directions of columns and rows of the sectional plates corresponding to the radial and tangential directions of the recording medium, and that the circuit unit (300) comprises:

an amplifier (310) for amplifying a sum signal of detection signals of the outer sectional plates (A1, B1, C1, D1); and

an adder (350) for adding a sum signal of detection signals of the inner sectional plates (A2, B2, C2, D2) and the output signal of the amplifier.

23. The reproduction signal detecting apparatus according to claim 22, wherein the circuit unit further comprises a time delay for time-delaying detection signals of the inner and/or outer sectional plates positioned in one row.

24. The reproduction signal detecting apparatus according to claim 22 or 23, wherein the respective light receiving regions are bisected such that the width of each of the inner sectional plates linearly increases from the center of the photodetector outward in the ± tangential directions.

FIG. 1 (PRIOR ART)

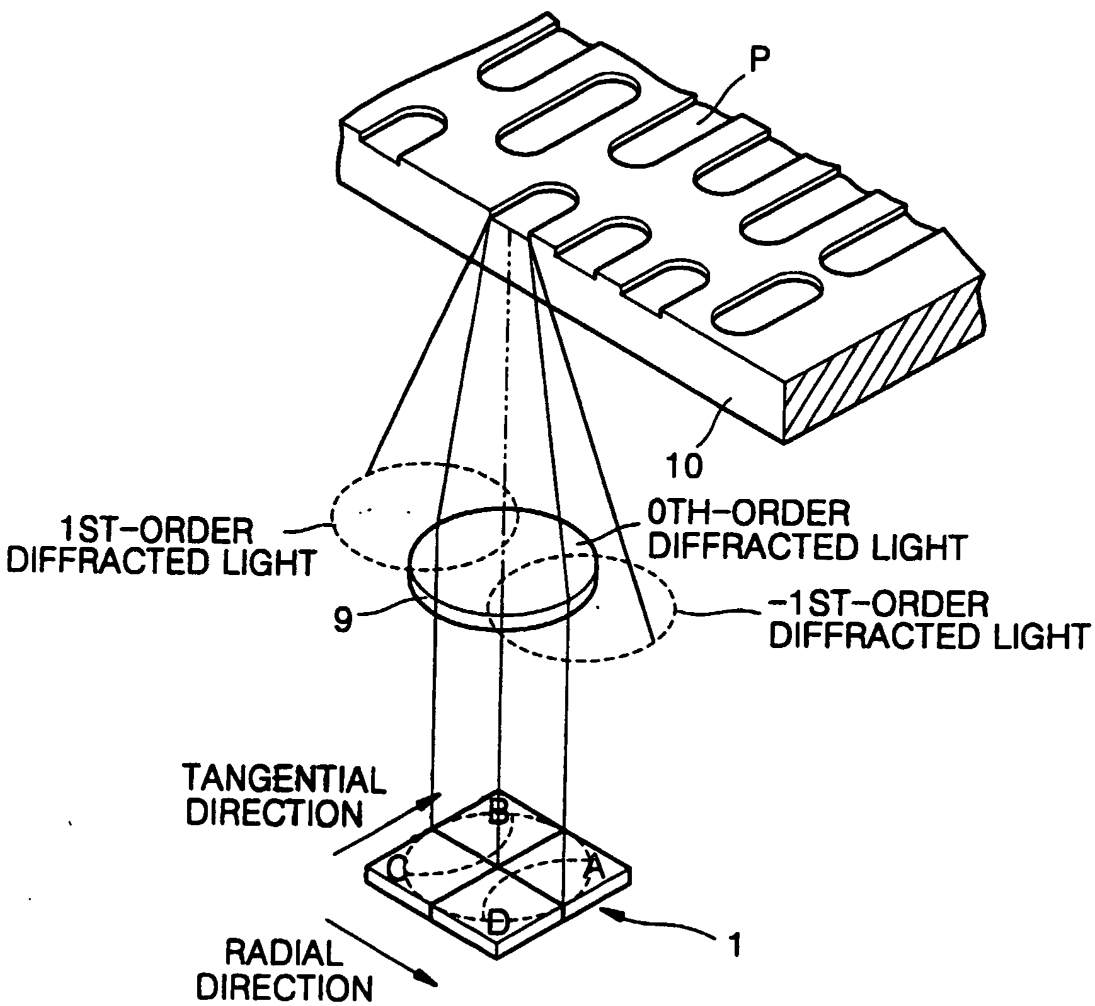


FIG. 2 (PRIOR ART)

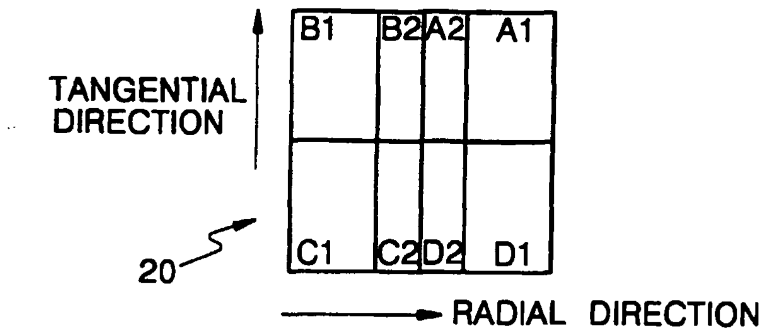


FIG. 3 (PRIOR ART)

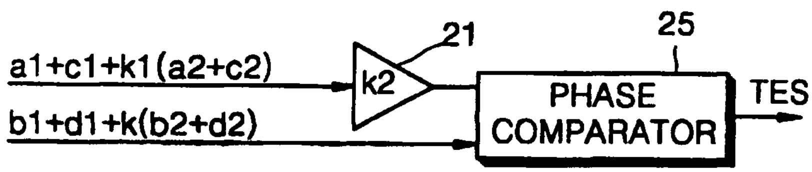


FIG. 4

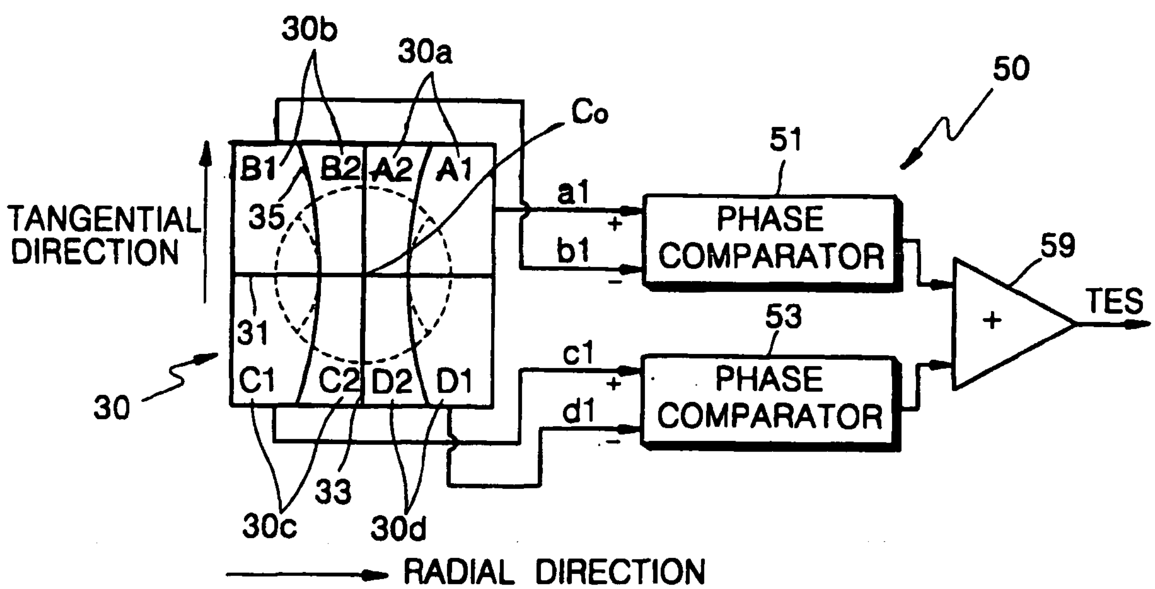


FIG. 5

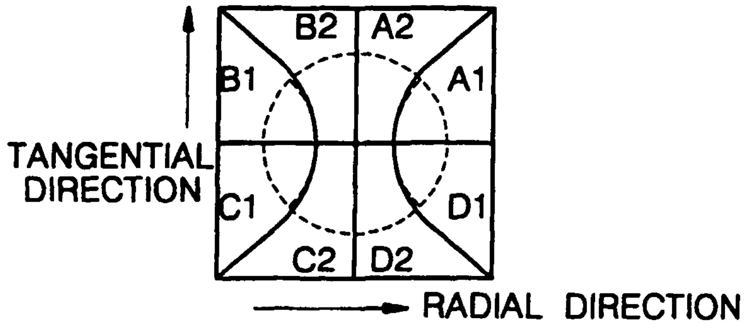


FIG. 6

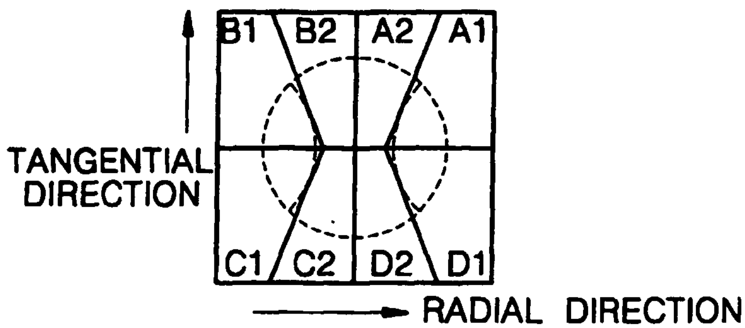


FIG. 7

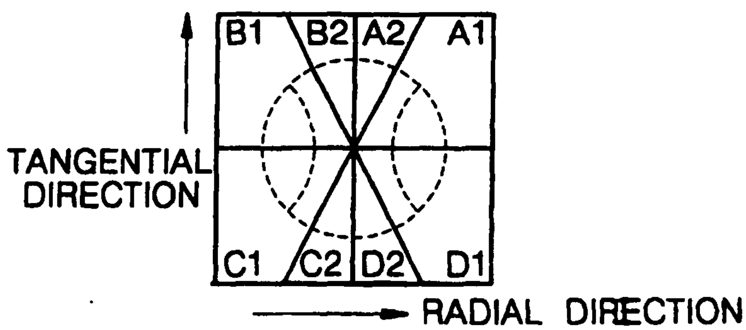


FIG. 8

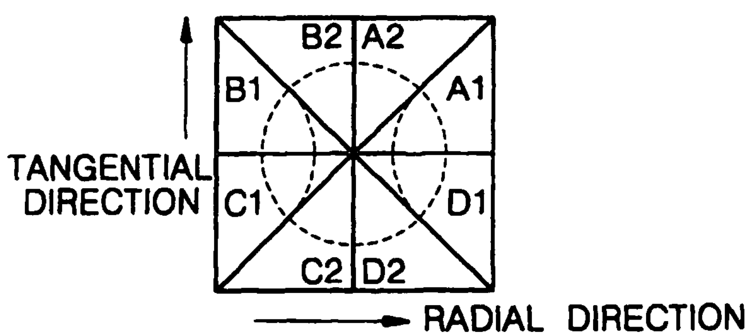
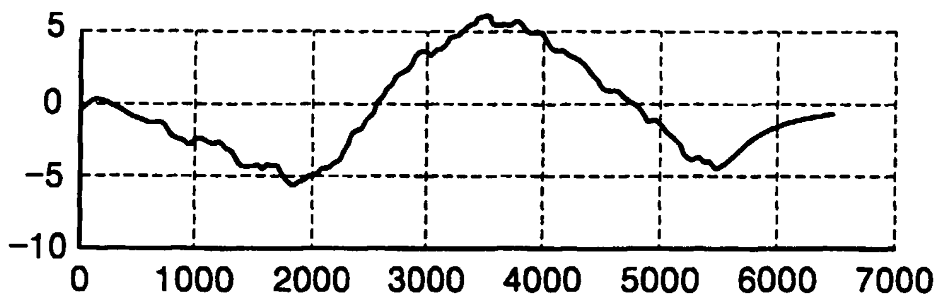


FIG. 9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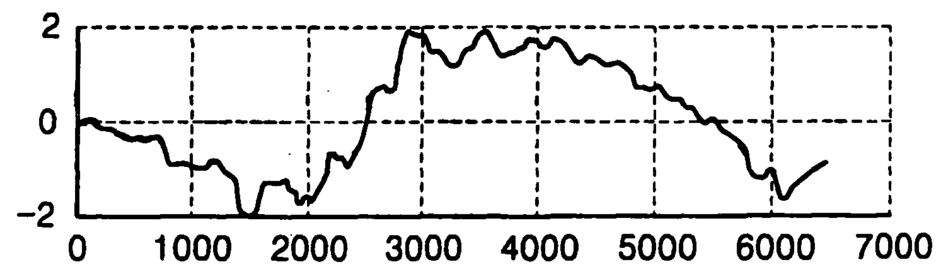
3000
4000
5000
6000
7000

FIG. 10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3000
4000
5000
6000
7000

FIG. 11

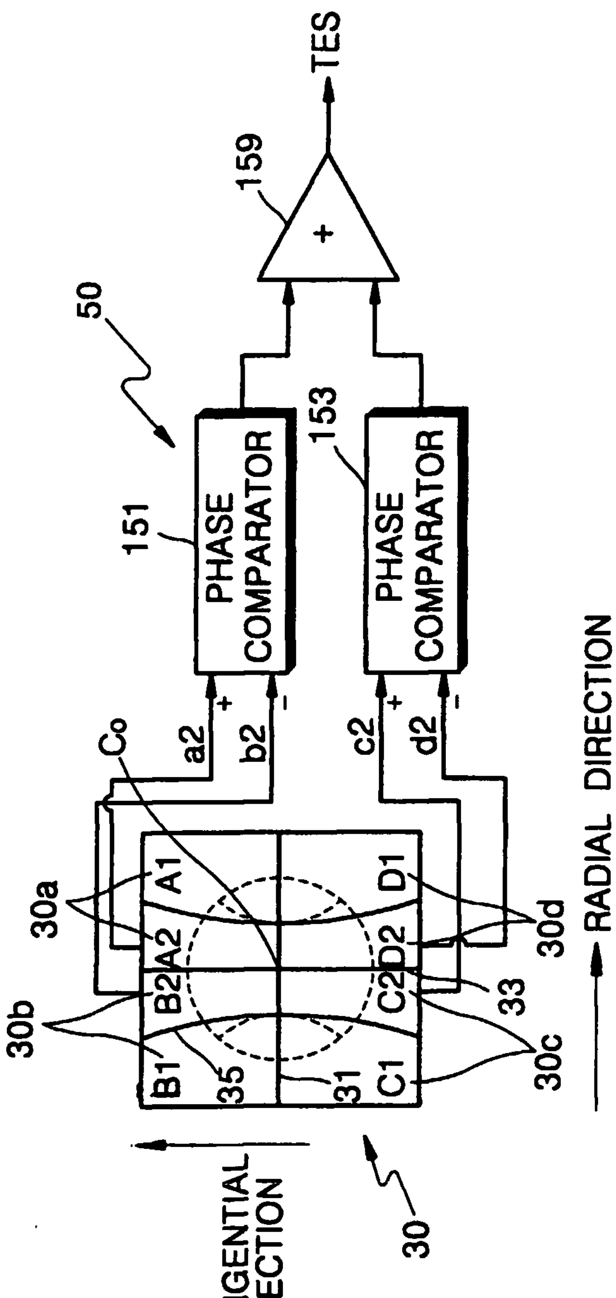

TES
159
+
50
151
PHASE COMPARATOR
153
PHASE COMPARATOR
a2
b2
c2
d2
+
-
+
-
Co
30a
A1
A2
B2
B1
30b
35
31
C1
C2
D2
D1
33
30c
30d
30
TANGENTIAL DIRECTION
RADIAL DIRECTION

FIG. 12

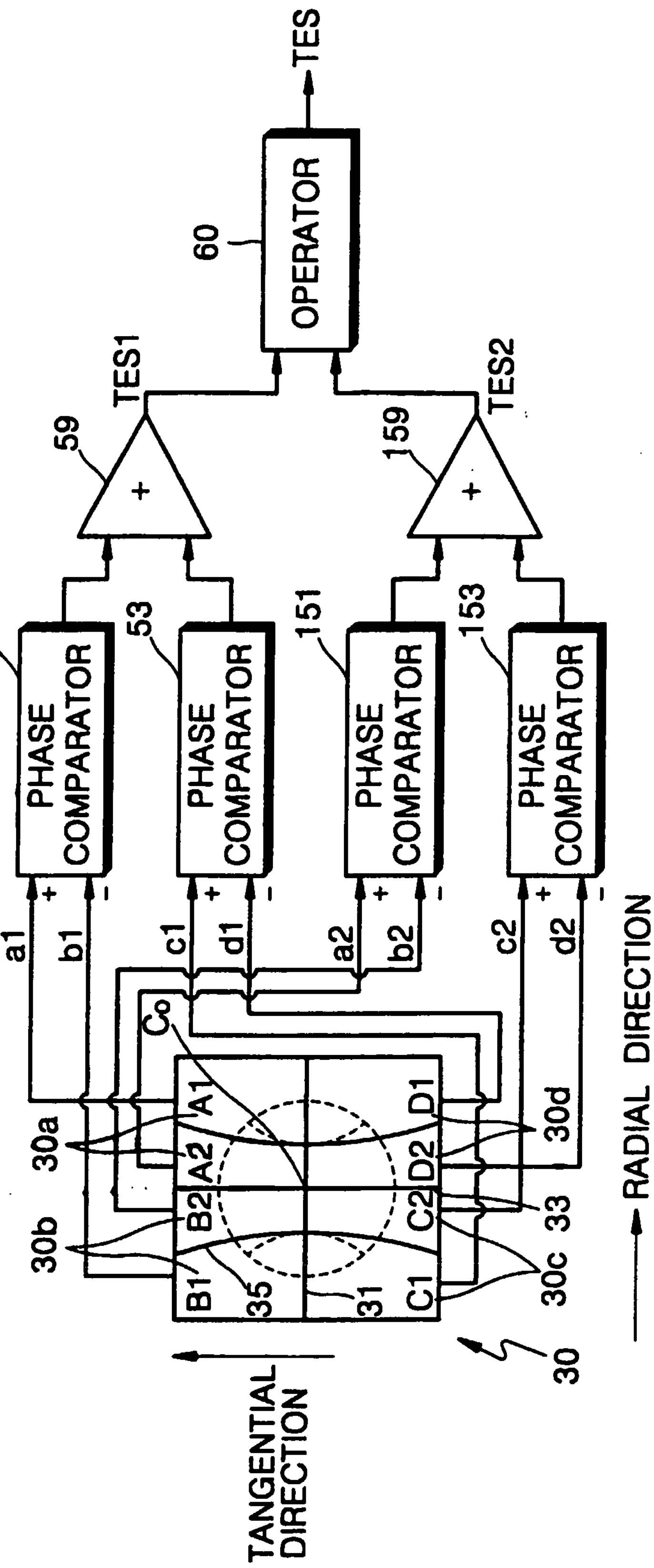

TES
OPERATOR
60
TES1
TES2
59
159
+
+
50
51
53
151
153
PHASE COMPARATOR
PHASE COMPARATOR
PHASE COMPARATOR
PHASE COMPARATOR
a1
b1
c1
d1
a2
b2
c2
d2
Co
A1
A2
B1
B2
C1
C2
D1
D2
30a
30b
30c
30d
31
33
35
30
TANGENTIAL DIRECTION
RADIAL DIRECTION

FIG. 13

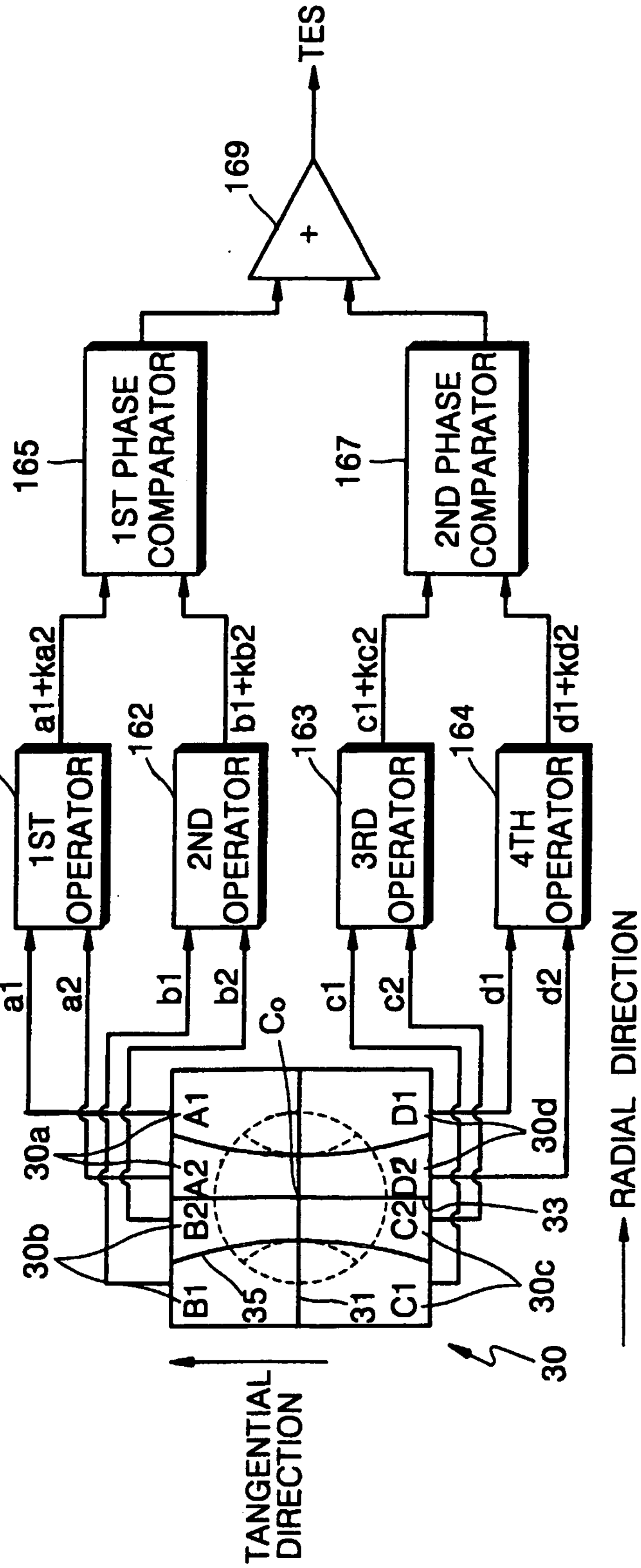

TES
169
+
50
165
1ST PHASE COMPARATOR
167
2ND PHASE COMPARATOR
a1+ka2
b1+kb2
c1+kc2
d1+kd2
161
1ST OPERATOR
162
2ND OPERATOR
163
3RD OPERATOR
164
4TH OPERATOR
a1
a2
b1
b2
Co
c1
c2
d1
d2
30a
30b
30c
30d
A1
A2
B1
B2
C1
C2
D1
D2
35
31
33
30
TANGENTIAL DIRECTION
RADIAL DIRECTION

FIG. 14

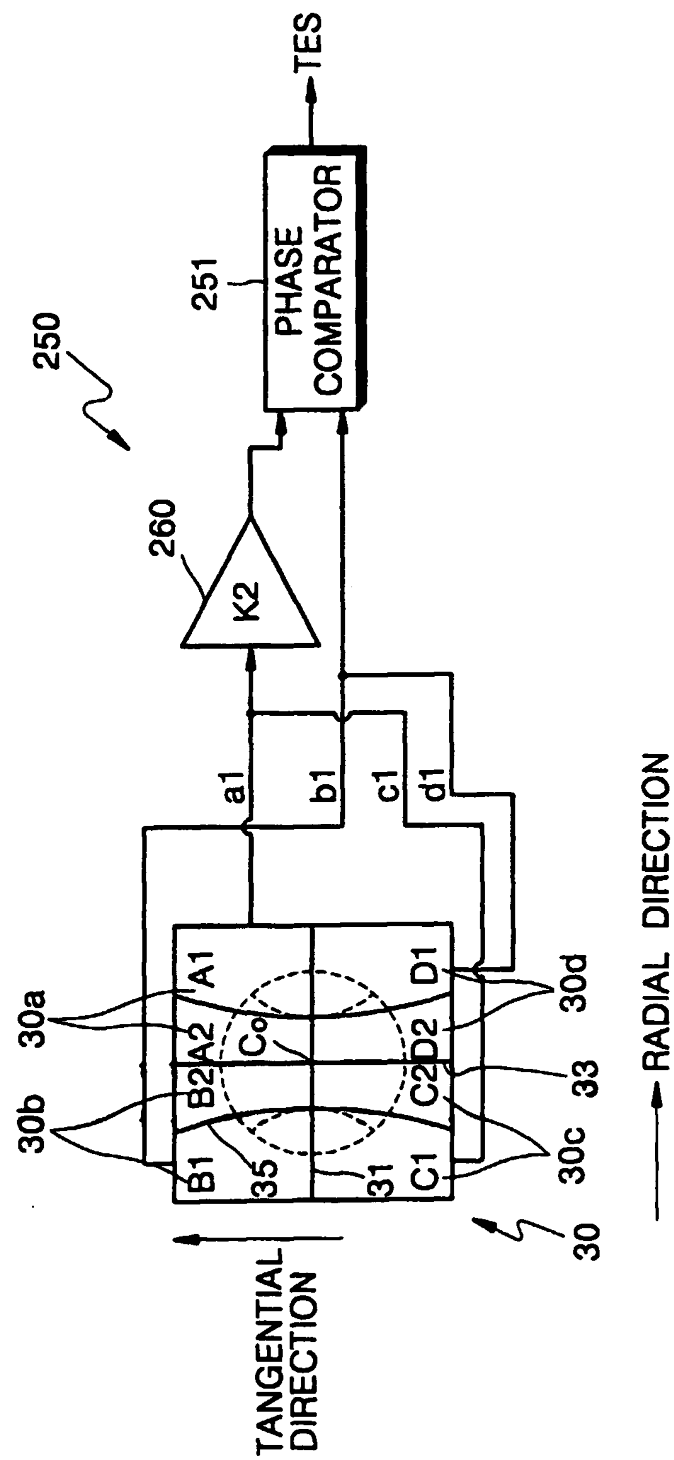

TES
PHASE COMPARATOR
251
250
260
K2
a1
b1
c1
d1
30a
30b
A1
A2
B2
B1
Co
D1
D2
C2
C1
35
31
33
30d
30c
30
TANGENTIAL DIRECTION
RADIAL DIRECTION

FIG. 15

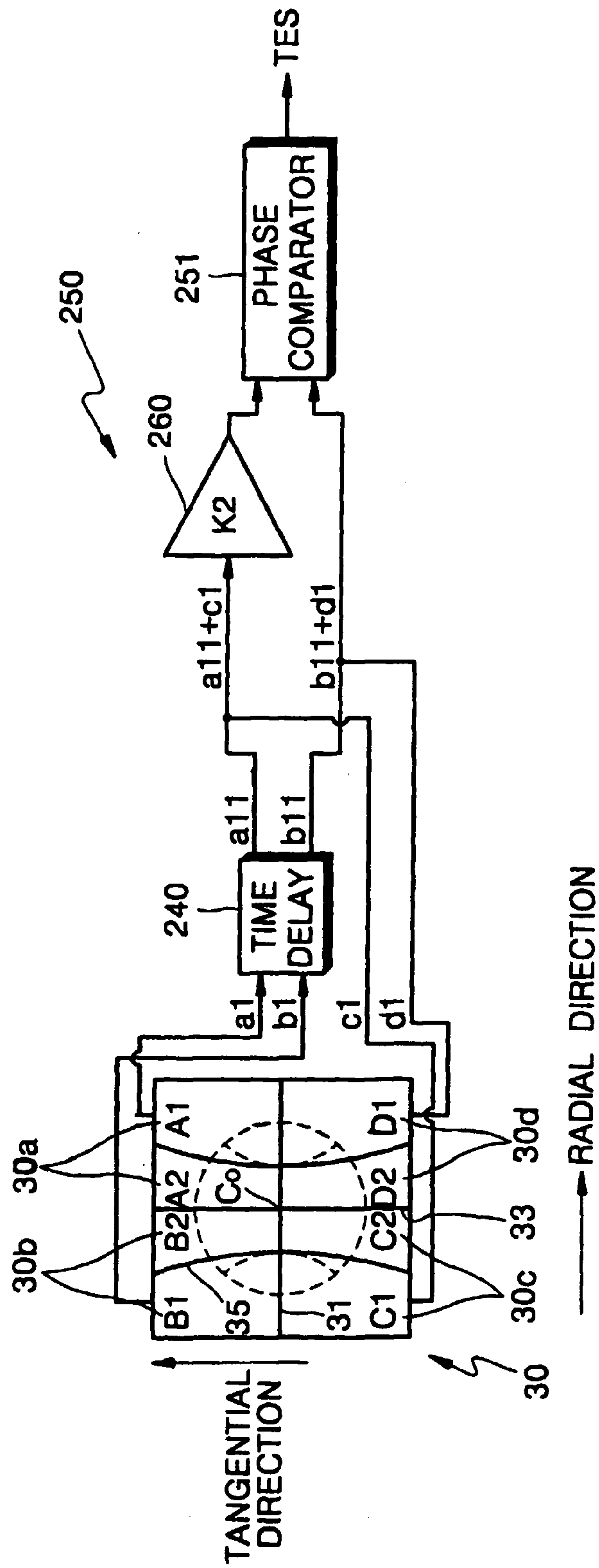

TES
PHASE COMPARATOR
251
250
260
K2
a11+c1
b11+d1
a11
b11
TIME DELAY
240
a1
b1
c1
d1
A1
A2
B2
B1
D1
D2
C2
C1
Co
30a
30b
30d
30c
33
35
31
30
TANGENTIAL DIRECTION
RADIAL DIRECTION

FIG. 16

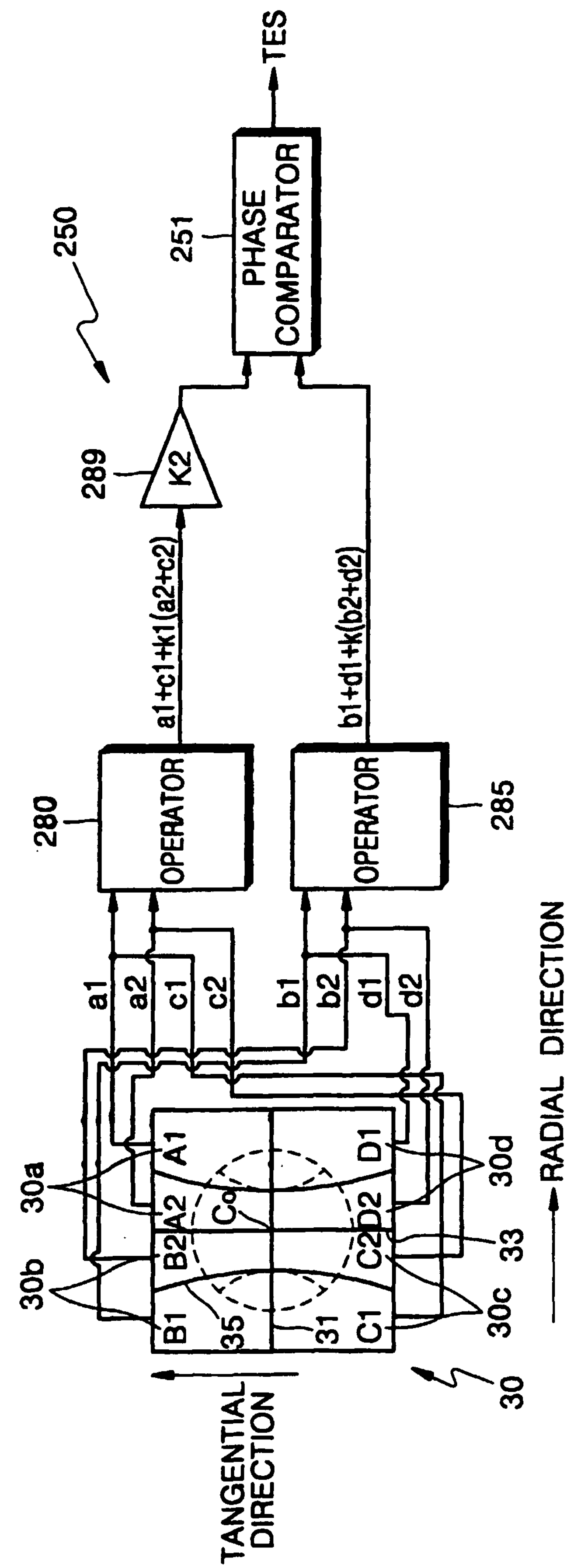
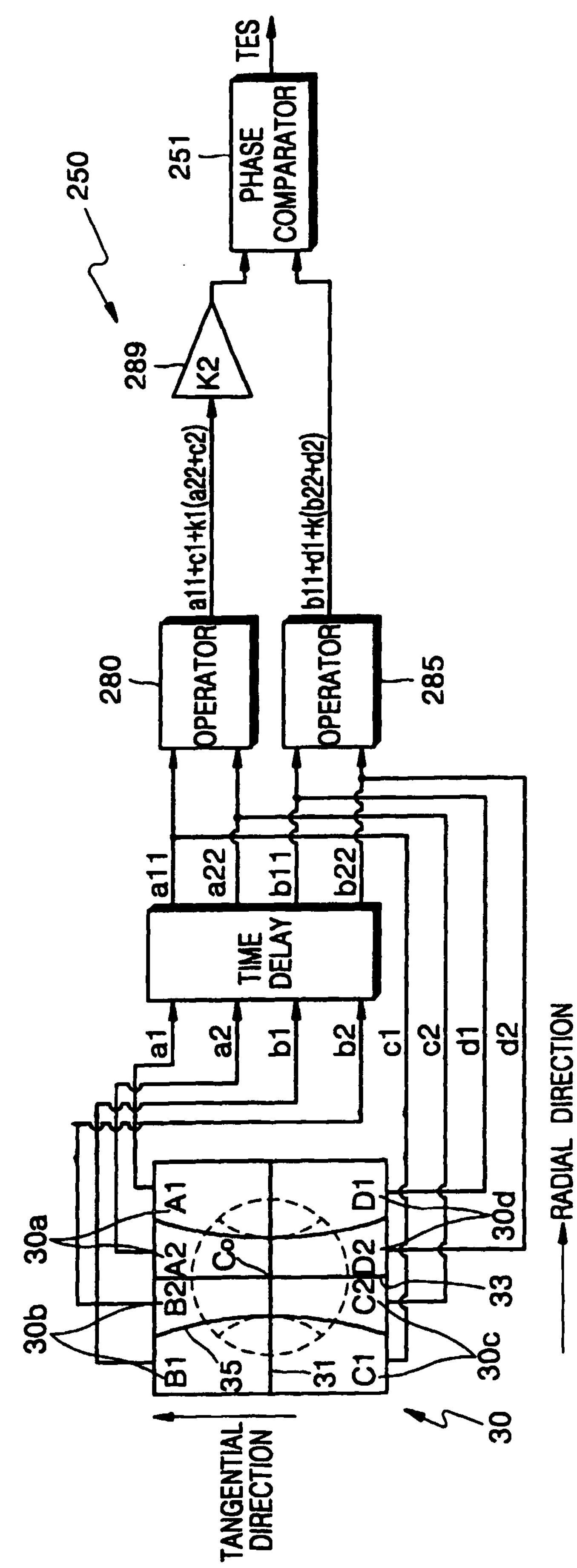
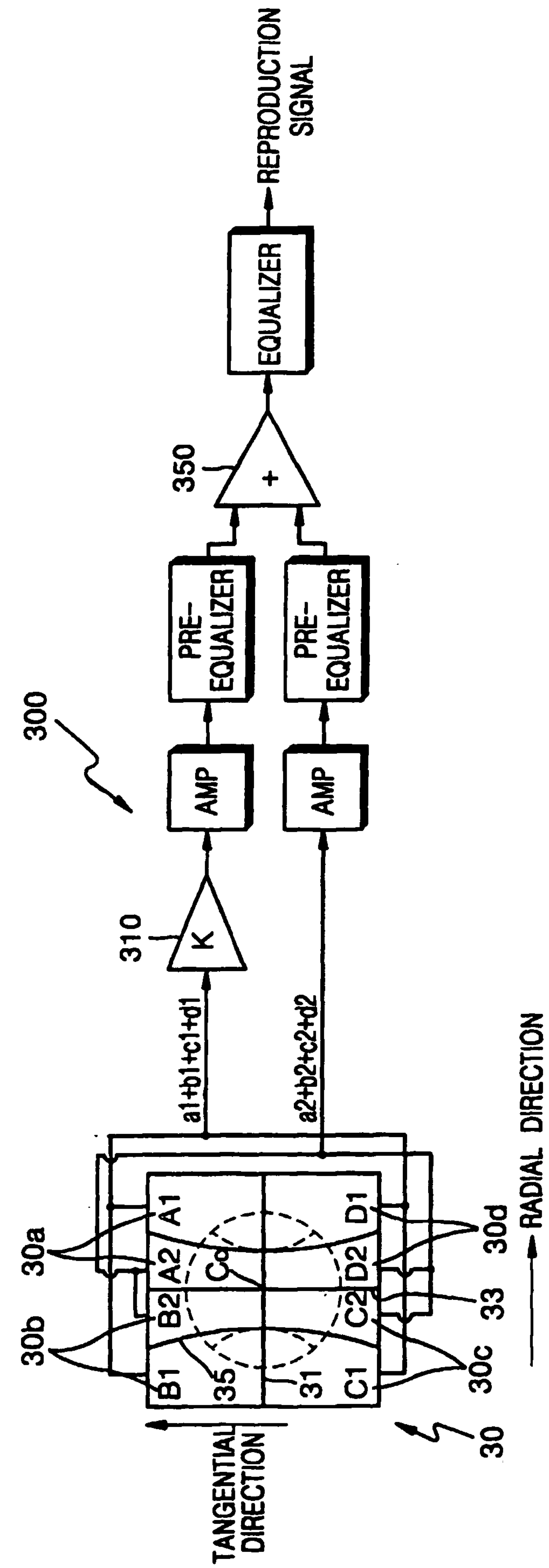

TES
PHASE COMPARATOR
251
250
289
K2
a1+c1+k1(a2+c2)
b1+d1+k(b2+d2)
OPERATOR
280
OPERATOR
285
a1
a2
c1
c2
b1
b2
d1
d2
30a
30b
30c
30d
A1
A2
B1
B2
C1
C2
D1
D2
Co
31
33
35
30
TANGENTIAL DIRECTION
RADIAL DIRECTION

FIG. 17



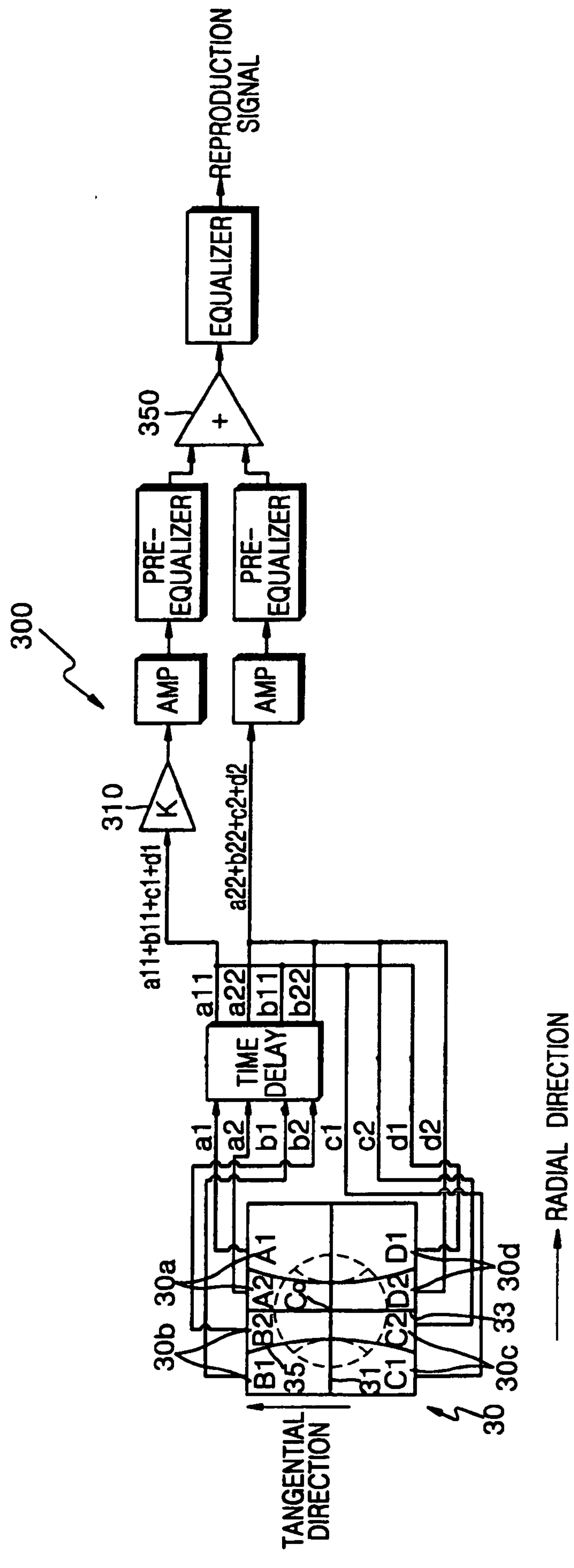
250
TES
251
PHASE COMPARATOR
289
K2
a11+c1+k1(a22+c2)
b11+d1+k(b22+d2)
280
OPERATOR
285
OPERATOR
a11
a22
b11
b22
TIME DELAY
a1
a2
b1
b2
c1
c2
d1
d2
30a
30b
30c
30d
A1
A2
B1
B2
C1
C2
D1
D2
Co
35
31
33
30
TANGENTIAL DIRECTION
RADIAL DIRECTION

FIG. 18



REPRODUCTION SIGNAL
EQUALIZER
350
+
PRE-EQUALIZER
PRE-EQUALIZER
300
AMP
AMP
310
K
a1+b1+c1+d1
a2+b2+c2+d2
30a
30b
30c
30d
A1
A2
B2
B1
C1
C2
D2
D1
Co
35
31
33
30
TANGENTIAL DIRECTION
RADIAL DIRECTION

FIG. 19


REPRODUCTION SIGNAL
EQUALIZER
350
+
PRE-EQUALIZER
PRE-EQUALIZER
AMP
AMP
300
310
K
a11+b11+c1+d1
a22+b22+c2+d2
a11
a22
b11
b22
TIME DELAY
a1
a2
b1
b2
c1
c2
d1
d2
30b
30a
B1
B2
A2
A1
Cd
35
31
C1
C2
D2
D1
30c
33
30d
30
TANGENTIAL DIRECTION
RADIAL DIRECTION